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FEASIBILITY STUDY ON THE USE OF SMALL-ANGLE NEUTRON SCATTERING --ETC(U)
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Progress Report,

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Feasibility Study on the Use of
Small-Angle Neutron Scattering for
Microstructural Determinations of Technological Alloys,
Carried out at Atomic Weapons
Research Establishment (AWRE),
Aldermaston, England.

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Progress Report

SANS Study of Technological Alloys at AWRE

Alloys which were (and are currently being) studied:

1. Titanium Alloy from Disc Section-Fatigue (Ti-6-4).
2. HY-130; Hydrogen Embrittlement of Notched Specimen.
3. Stainless Steel (Type-304) - creep study.
4. Pure Iron-Hydrogen Embrittlement.
5. UDIMET 700 - HIP; Heat treated and Aging study.
6. Incoloy.
7. Hastelloy.
8. Inconel.
9. Aluminum Oxide - (Alumina) - Prestressed and Sintered Varying Densities.

This study, which is aimed at showing feasibility, was carried out by this investigator at "The Atomic Weapons Research Establishment", Aldermaston, England (AWRE). AWRE is a laboratory administered by the Ministry of Defense, U. K.

This preliminary research program on non-destructive evaluation using small-angle neutron scattering (SANS), was initiated and supported by the Naval Air Systems Command and the Office of Naval Research. The central goal of this aspect of the effort was to show feasibility of SANS through studies of technological alloys in conjunction and at AWRE. This investigator spent the month of July working together with Dr. R. Miller and his associates on the HERALD REACTOR. In a previous report written by this investigator, (Non-Destructive Evaluation of Materials with Cold Neutron Beams - Contract No. N00019-77-M-0418 - December, 1977), the details of SANS and the AWRE facility were described. Since that time, a LETI area detector was installed and tested. In the main, the computer hardware has been installed, and software programs are operational, with only minor debugging being required. During this investigator's stay at AWRE, there were minor problems which were encountered: eg., absence of an interface between the data acquisition system and the data analysis computer. This

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necessitated the transfer of data by paper tape which was mainly inefficient and annoying, but not really an essential problem.

Overall, during my stay, the computer systems operated ably and the reactor and cold source worked perfectly. There were no shutdowns following the original reactor startup cycle.

Since HERALD is limited to 5 megawatts, the flux output was low, but an experiment could be carried out in 2 hours for a strongly scattering system. Thus, a large number of experiments could be carried out during this investigator's visit to AWRE.

Dr. Miller will continue a number of the runs which were not completed. These results will be reported in the Final Report on this contract.

Below are given the experimental runs which were carried out and those currently underway. The details of these experiments and the findings will be given in the Final Report.

The range of experiments which were carried out and which are still undergoing study-to-completion will be presented according to the following scheme:

- I. Experiment
 - A. Alloy
 - B. Contact
 - C. Type of experiments performed
 - D. Results

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- I. Fatigue of Ti-Alloy Disk (Webs and rims)
 - A. Ti-6V-4Al.
 - B. Dr. G. London, NAVAIR.

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- C. SANS at central reduced section and at non-loaded end. A large number of experiments were performed at AWRE. In addition, Dr. M. Suenaga of Brookhaven National Laboratory and Dr. G. Kostorz of Max-Planck-Institut, Stuttgart carried out measurements on one of these specimens at ILL, Grenoble, France, at longer wavelengths and at considerably greater neutron fluxes.
- D. An increase has been detected in scattered intensity which is attributable to fatigue. Theoretical and experimental studies were carried out to evaluate double-Bragg scattering due to the $Ti_3 Al (\alpha')$ phase.
- In addition to SANS studies, cold neutron radiography (CNR) was studied of these specimens. In one very interesting case, the utility of CNR was demonstrated when the full extent of a crack was observed with CNR; with normal thermal neutron radiography, the crack was barely noticeable. The plates will be included in the final report of this study.

II. Hydrogen Embrittlement of HY-130

- A. HY-130 steel
- B. Mr. Zannis, NSRDC, Annapolis, Maryland.
- C. To be completed - in situ
charging of notched fracture mechanics specimens.

III. Hydrogen Embrittlement of Iron

- A. Pure Iron
- B. Dr. M. Suenaga, Brookhaven National Laboratory
- C. Hydrogen introduced at 475°C under pressure of 900 psi for up to 70 hours. Methane bubbles presumed to have formed
- D. Clear scattering, dependent on amount of hydrogen, at Porod region due to voids

IV. Creep of Stainless Steel

- A. Type 304 stainless steel
- B. Dr. M. Suenaga, Brookhaven National Laboratory
- C. Creep of 304 stainless steel at 575°C - interruption experiment
- D. Significantly increased scattering at the Porod region (higher angle portion of the SANS regime), clearly indicative of void formation. Effect is dependent on time of creep.

V. Hot-Isostatic Pressed Superalloy

- A. UDIMET 700
- B. Dr. V. Wilms, MTU, Munich
- C. Heat treated and ageing of HIPPID UDIMET 700
- D. SANS shows excellent results for the aged specimens, the small second phase, 70 Å, being clearly identifiable and comparable with accepted TEM results.

VI. Miscellaneous Superalloys

Incoloy, Hastelloy, HIPPED alloys, Inconel (creep failure specimen) are currently under study at AWRE. Some preliminary results indicate that the scattering is strong. The results will be included in the final report.

VII. Pressed and Sintered Pure Al_2O_3

These specimens are available to us in densities ranging from ~60% - ~100% of theoretical density. The specimens scatter very strongly due to large internal surface areas. The final results will be contained in the final report.

Conclusions

At this stage it can be concluded that SANS represents a good pos-

sibility for an effective method of metallographic analysis. The technique affords the possibility of evaluating average bulk effects in both two phase precipitation strengthenable alloys and in void-containing systems. It is clear to us that long wavelength neutrons are essential for most of the technological work which we encountered, i.e. a cold source.

The above experiments were carried out principally at AWRE, Aldermaston, but several were also carried out at ILL, Grenoble.

The final report (due by October 31, 1978) will detail the results.